Biologically Inspired Intelligent Robotics

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This Symposium covers the recent advances and trends in biomimetic robots, that is, the emulation of life using robotic machines [Bar-Cohen and Breazeal, 2003]. The field of biomimetics has blossomed in recent years, where numerous advances are combined into machine intelligence, materials science, and biological science's understanding of life's wondrous mechanisms, biomimetics and its sibling, integrative biology. These advancements allowed scientists and engineers to reverse engineer many of animals' functional systems, and to implement these systems technologically. This interdisciplinary work has resulted in machines that can recognize facial expressions, understand speech, and locomotion in robust bipedal gaits, similar to humans. Additionally, advances in polymer sciences have resulted in artificial muscles that show functional characteristics remarkably similar to biological muscle tissue. The accelerating pace of change in these fields seems to make evident that the emergence of machines as our peers is imminent. Although this topic brings with it enormous implications including but not limited to questions regarding the nature of evolution and its role in technological progression, this Symposium focuses primarily on current developments in the field and its related disciplines as well as the technical challenges. Some of the topics that will be covered include Artificial Muscles, Psychology of Biomimetic Robots, Integrative Biology, and Biomimetic Animated Creatures and Artificial Life, Functionality Elements of Biomimetic Robots, and Applications for Biologically Inspired Intelligent Robotics.

Generally, with today's technology one can quite well graphically animate the appearance and behavior of biological creatures. However, in past years, engineering such biomimetic intelligent creatures as realistic robots was hampered by physical and technological constraints and shortcomings. Making such robots that can hop and land safely without risking damage to the mechanism, or making body and facial expression of joy and excitement are very easy tasks for human and animals to do but extremely complex to engineer. Advances in biologically-inspired technologies are increasingly enabling the emulation of creatures making biomimetic intelligent robots in realistic forms. This technology advancement may reach one day a point that viewers will react with "Gosh, this robot looks unbelievably real!" just like the reaction to an artificial flower. The use of artificial intelligence, effective artificial muscles and other biomimetic technologies are expected to make the possibility of realistically looking and behaving robots into more practical engineering models.

Making biologically inspired intelligent robots requires understanding the biological models as well as advancements in analytical modeling, graphic simulation and the physical implementation of the related technology. The research and engineering areas that are involved with the development of biologically-inspired intelligent robots are multidisciplinary and they include materials, actuators, sensors, structures, functionality, control, intelligence and autonomy. While the engineering challenges are very interesting to address there are also fundamental issues that need to be addressed. Some of these issues include self-defense, controlled-termination as well as many others. There is already extensive heritage of making

robots and toys that look and operate similar to biological creatures and models for such robots are greatly inspired by science fiction and the entertainment industry (movies, toys, animatronics, etc.). These models have created perceptions and expectations that are far beyond the reach of current engineering capabilities, which are constrained by laws of physics and the current state-of-the-art.

Graphics

<u>NOTE:</u> A high-resolution version will be sent to AAAS with the final version
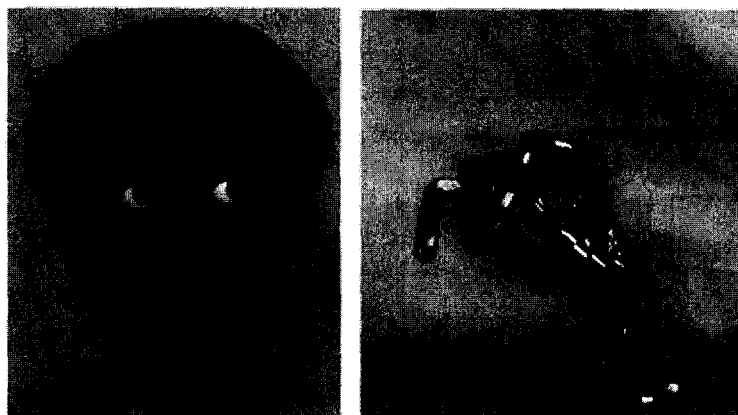
CAPTION: An android head and a robotic hand that are serving as biomimetic platforms for the development of artificial muscles

BIOMIMETIC ACTUATION MATERIALS
Yoseph Bar-Cohen, Jet Propulsion Lab

Muscles are responsible for the mobility and manipulation capability of biological creatures and they are considered highly optimized systems since, in spite of millions of years of evolution, they are fundamentally the same for all animals. Natural muscles are driven by a complex mechanism and are capable of lifting large loads with short response time (milliseconds). The potential for developing actuators with performance characteristics that rival that of muscle is increasingly becoming feasible with the emergence of effective electroactive polymers (EAP). Such polymers have many attractive characteristics including low weight, fracture tolerance, and pliability. EAP materials have functional similarities to biological muscles, including resilience, damage tolerance, and large actuation strains (stretching, contracting or bending). EAP-based actuators may be used to eliminate the need for gears, bearings, and other components that complicate the construction of robots and are responsible for high costs, heavy weight and premature failures. Further, they can be configured into almost any conceivable shape, their properties can be engineered, and they can potentially be integrated with micro-electro-mechanical-system (MEMS) sensors to produce smart actuators. Visco-elastic EAP materials can potentially provide more lifelike aesthetics, vibration and shock dampening, and more flexible actuator configurations. Exploiting the properties of artificial muscles may enable even the movement of the covering skin to define the character of the robots and provide expressiveness.

The field of artificial muscles offers many important capabilities for the engineering of robots that are inspired by biological models and systems. The easy capability to produce EAP in various shapes and configurations can be exploited using such methods as stereolithography and ink-jet processing techniques. Potentially, a polymer can be dissolved in a volatile solvent and ejected drop-by-drop onto various substrates. Such rapid prototyping processing methods may lead to mass-produced robots in full 3D details including the actuators allowing rapid prototyping and quick transition from concept to full production [Bar-Cohen, 2001]. A possible vision for such technology might be the fabrication of insect-like robots that can be made to fly and pack themselves into the packaging box to be ready for shipping once they are made. Other example can be the use of a movie script to produce the needed robots, which can be modified rapidly as needed for the evolving script. Further, as defense is required to do more with much less resources, the use of inexpensive and affordable technologies are becoming increasingly critical to assuring cutting-edge capability while meeting budget constraints. Using improved EAP-based miniature biomimetic robots can significantly add to current capabilities as well as enable novel new ones. Biologically inspired robots may be developed with capabilities that are far superior to natural creatures since they are not constrained by evolution and survival needs, examples may include artificial bugs that may walk on water, swim, hop, crawl and walk while reconfigure themselves as needed when required.

Making insect-like robots may be used to inspect hard to reach areas of the interior of aircraft structures or engines where the creatures can be launched to conduct the inspection procedures and download the data upon exiting the structure. Important addition to this capability can be the application of telepresence combined with virtual reality using haptic interfaces. While such capabilities are expected to significantly change future robots, additional effort is needed to develop robust and effective polymer-based actuators.

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CAPTION: Grand challenge for the development of EAP actuated robotics.

ROBOTIC BEHAVIOR

Cynthia Breazeal, MIT Artificial Intelligence Laboratory

BIOMIMETIC ROBOTS

David Hanson, University of Texas-Dallas

REFERENCES

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http://ndeaa.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm

CV

Yoseph Bar-Cohen is a physicist specializing in electroactive materials and mechanism and ultrasonic NDE. He is a Senior Research Scientist, and a Group Leader at JPL (http://ndeaa.jpl.nasa.gov/). He is a Fellow of SPIE and ASNT and also an Adjunct Professor at UCLA. He received his Ph. D. in Physics (1979) from the Hebrew University, Jerusalem, Israel. His notable discoveries include the leaky Lamb waves (LLW) and polar backscattering phenomena in composite materials. He made over 230 publications, numerous presentations at national and international conferences, Chaired/CoChaired 15 Conferences, has 15-registered patents and he is the editor of 2 books, including one on Electroactive Polymers. He is the initiator of the SPIE Conf. on EAP, chairing it since 1999. His scientific and engineering accomplishments have earned him the 2001 NASA Exceptional Engineering Achievement Medal, the 2001 SPIE's NDE Life Time Achievement Award and many other honors and awards.